JSC/White Sands Test Facility
Safety & Health Program

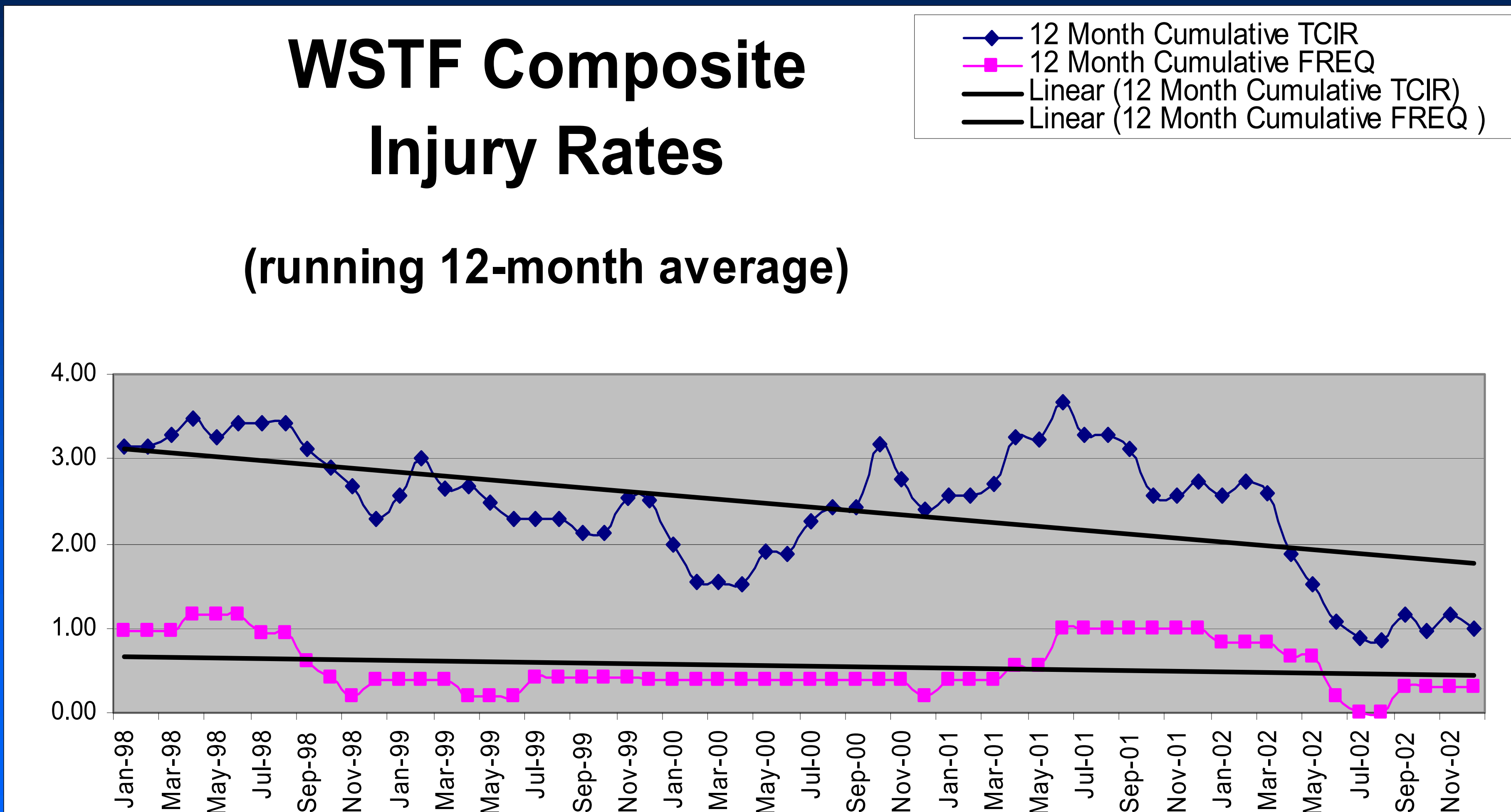
Objectives & Lessons Learned

WSTF Safety & Health Program

Injury Reduction Objective
- **Tactical Initiatives**
- **The Numbers**
- **Occupational Health**

Lessons Learned
- **Large Altitude Simulation System (LASS) Mishap**
- **Hypervelocity Impact Industrial Hygiene Case Study**

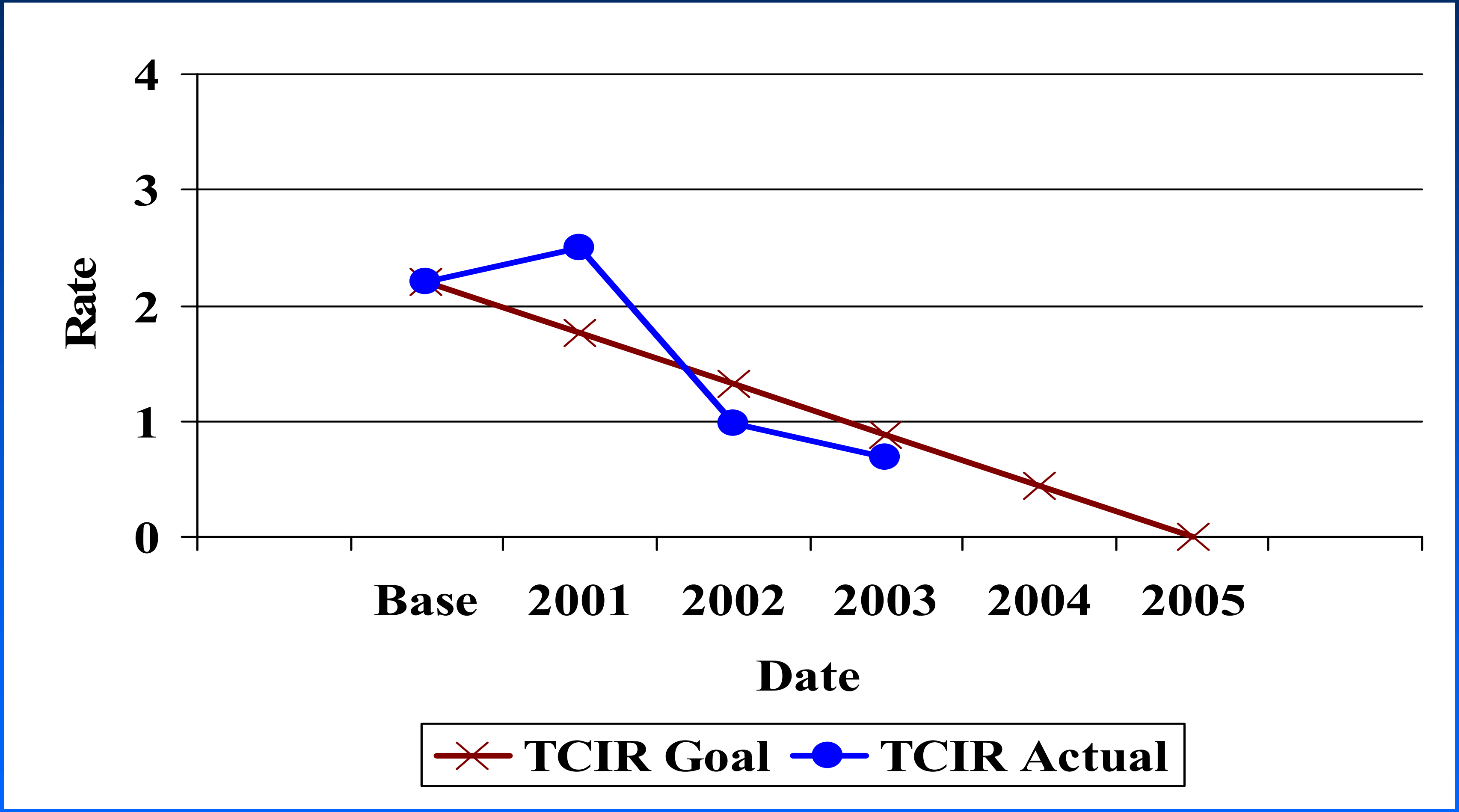
The Numbers --


WSTF Composite
Injury Rates
(running 12-month average)
12 Month Cumulative TCIR
12 Month Cumulative FREQ
Linear (12 Month Cumulative TCIR)
Linear (12 Month Cumulative FREQ)
4.00
3.00
2.00
1.00
0.00
Jan-98
Mar-98
May-98
Jul-98
Sep-98
Nov-98
Jan-99
Mar-99
May-99
Jul-99
Sep-99
Nov-99
Jan-00
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02

Tactical Initiatives --

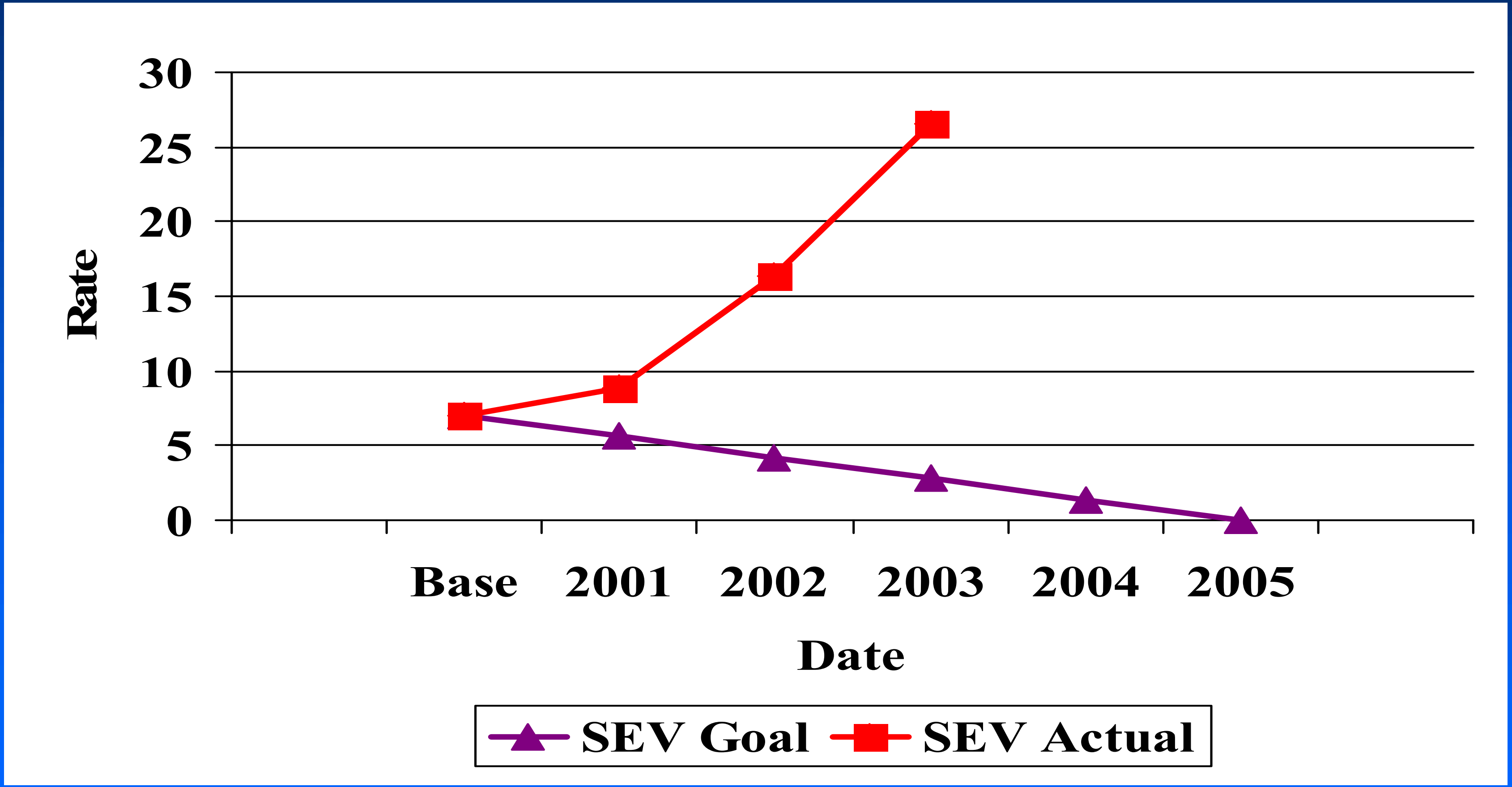
- **WSTF Injury Reduction Objective: Reduce each year's injury and severity rates by 20% per year from the 1998–2000 baseline.**
  - Tactical actions for injury reduction objective developed with Honeywell Safety
    - Winning Hearts & Minds
    - Bolstering Employee Responsibility
    - Sharpening Awareness
    - Programming Hazard Abatement
  - Currently rolling out organizational Safety & Health Plans to drive
    - Employee involvement in hazard inspection and abatement
    - Supervisory concern for employee welfare & ID of behavioral hazards
  - Incomplete: Injury rates decreased over 60% from 2000 baseline, however Severity rate up 100% over 2001
- **Electric Code Compliance Objective: Correct ALL Electrical noncompliances by 2005.**
  - Successful: Code noncompliances reduced >60% below 2000 baseline

Injury Reduction Objectives (TCIR)



Injury Reduction Objectives (Severity*)

*Does not include restricted days.



Snake bit? -- Recent lost-time injuries

- Logistics employee cut-off in city traffic resulting in whiplash symptoms
- NASA Division Chief dislocates toe in Safety & Total Heath Day dunking booth
- Security guard aggravates wrist injury lifting material for shredding
- Security guard suffers head concussion when back of chair breaks

Occupational Health --

- Occupational Health Principle Center Assessment
  - Overall significant improvement of WSTF OH Program
  - Inconsistent medical records review for health trends
  - Continue advancement of OH/EMS qualifications
  - “Impressive” working relationship of IH resources
  - Assess Fuel Lab vent hood proliferation for interference
  - Improve radiation use authorization records maintenance
  - Successful EAP program implementation
- Physician Turnover
  - Dr. Henry Hosford retired 2000
  - Dr. Robert Baker dropped contract 2001
  - Dr. Ed Kennedy dropped contract 2002
  - Dr. Wolfgang Haese retained January 2003
- Nursing staff
  - Jeanette Moore passed away (over 30 years of service at WSTF)
  - New Registered Nurse -- Carolyn Ricks-Ryder

WSTF Large Altitude Simulation System (LASS) Mishap

September 11, 2003

WSTF LASS Mishap

24 Inch Steam Line Expansion Loop Before & After

Before

After

Summary of Event -- 9/11/03

- Failure Occurred in the 24 inch Steam Feedline to Test Stand 401 Steam Ejector System
  - 30 Seconds into a Test Stand 401 Validation Run Prior to a Minuteman 4th Stage Test
- Section of Line Ruptured at Approximately 260 psig Due to Corrosion Induced Thinning
  - Normal Operating Pressure is 300 psig
- Several Pieces of Pipe Dislocated from Event Site
- No Personnel Injuries
- Very Minor Collateral Facility and Equipment Damage
- Excellent WSTF Personnel Response

Summary of Findings

- Internal Corrosion/Erosion Made Worse by LASS Design and Typical Operation
- Weather, Training, Equipment, Procedures Not Factors
- Appreciation for the Degree of Wall Thinning and Follow-up to Address Known Issues Were Inadequate
- Test Operations Approval Process Holes Exist
- LASS Steam Line Hazard Identification, Documentation, and Control Were Deficient
- Successful LASS Runs Reinforced a "Comfort Zone" Among Personnel
- Failure Mode Was Unique to LASS, But Provides Important Design Lessons

Description of LASS

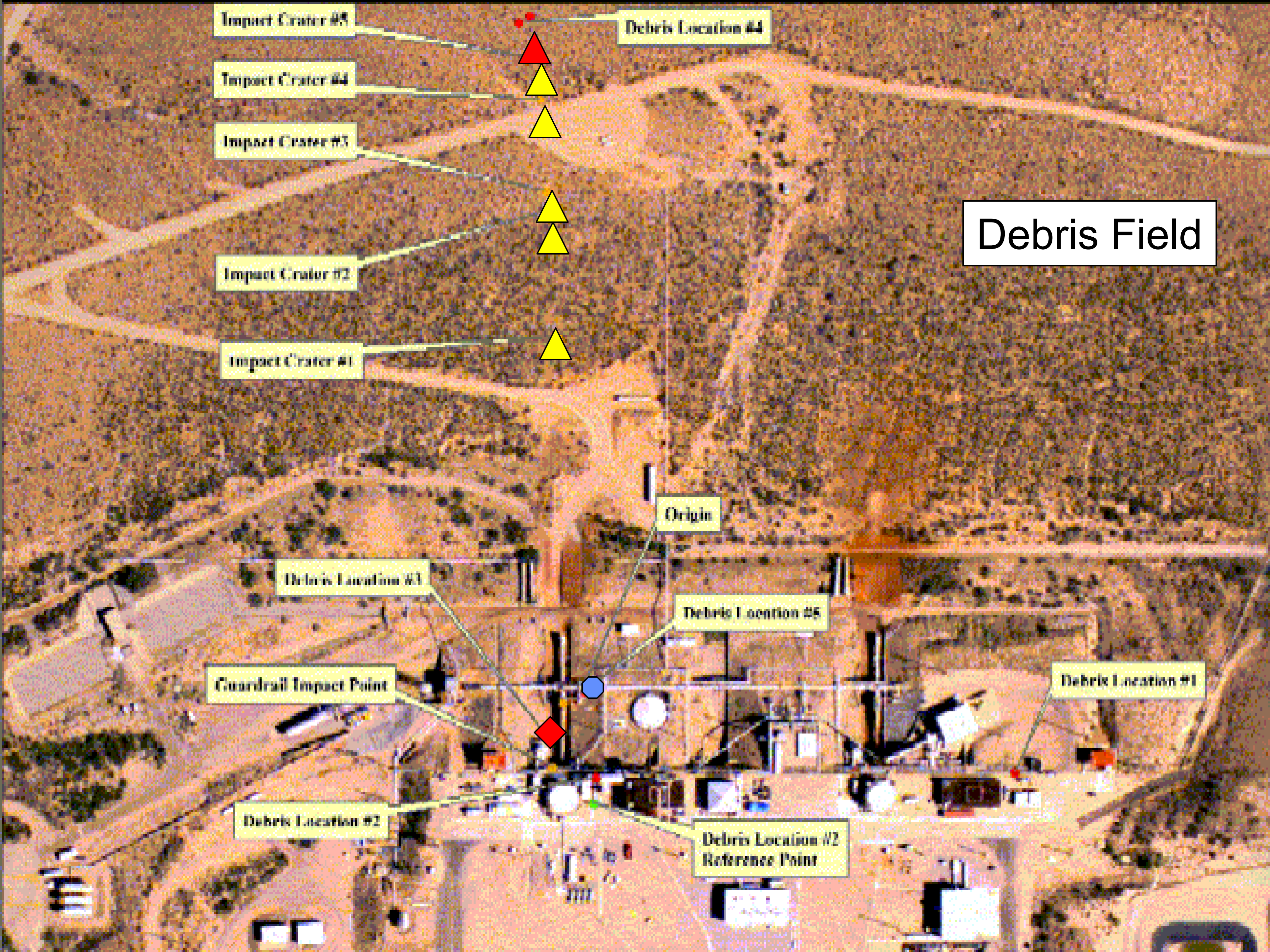
- Chemical Steam Generator

  - Three X-15 Like Injector Modules
    - LOX/Alcohol Combustion with Water Injection Into the Exhaust
  - Provides up to 540 lbs/sec of ~300 psig, 500 °F Steam
- Distribution

  - 30" Steam Line Feeds Test Stands 401 and 403
    - 30" Valve isolates TS 403 for TS 401 Runs
  - 24" Expansion Loop Feeds Test Stand Ejectors, and Absorbs Thermal Expansion of the Ejector
    - 24" Valve on TS 401 for Isolation During TS 403 Runs
- Installed in 1964 to Support Apollo LEM and SPS

Description of Mishap

- LASS Validation Run # 2009 Operations Timeline
  - 06:30 Electrical and mechanical Set-ups & Check-outs
  - 14:00 15 Minute Announcement
  - 14:16:30 LOX Pumps Start – LOX, IPA, H2O Pressures OK
  - 14:17:39 Prop & H2O Valves Open, Spark Plugs Fire
  - 14:17:48 Main Prop Valves Open, "Full Steam" Indicated
  - 14:18:00 Module P = 241 psig, TS 401 Ejector P = 232 psig
  - 14:18:05 Module P = 271 psig, TS 401 Ejector P = 260 psig
  - 14:18:06 24" Expansion Loop Ruptures
  - 14:18:08 Module P = ~ 70 psig, TS 401 Ejector P = ~ 2 psig
  - 14:18:10 "STOP" and "VENT" Buttons Depressed
  - 14:18:13 Module P = ~ 0 psig
  - 14:35 Diesel Engines Shut Down



Debris Field
Impact Crater #5
Debris Location #4
Impact Crater #4
Impact Crater #3
Impact Crater #2
Impact Crater #1
Origin
Debris Location #3
Debris Location #5
Guardrail Impact Point
Debris Location #1
Debris Location #2
Debris Location #2 Reference Point

Super Flyer

Desert Walker

Catawampus

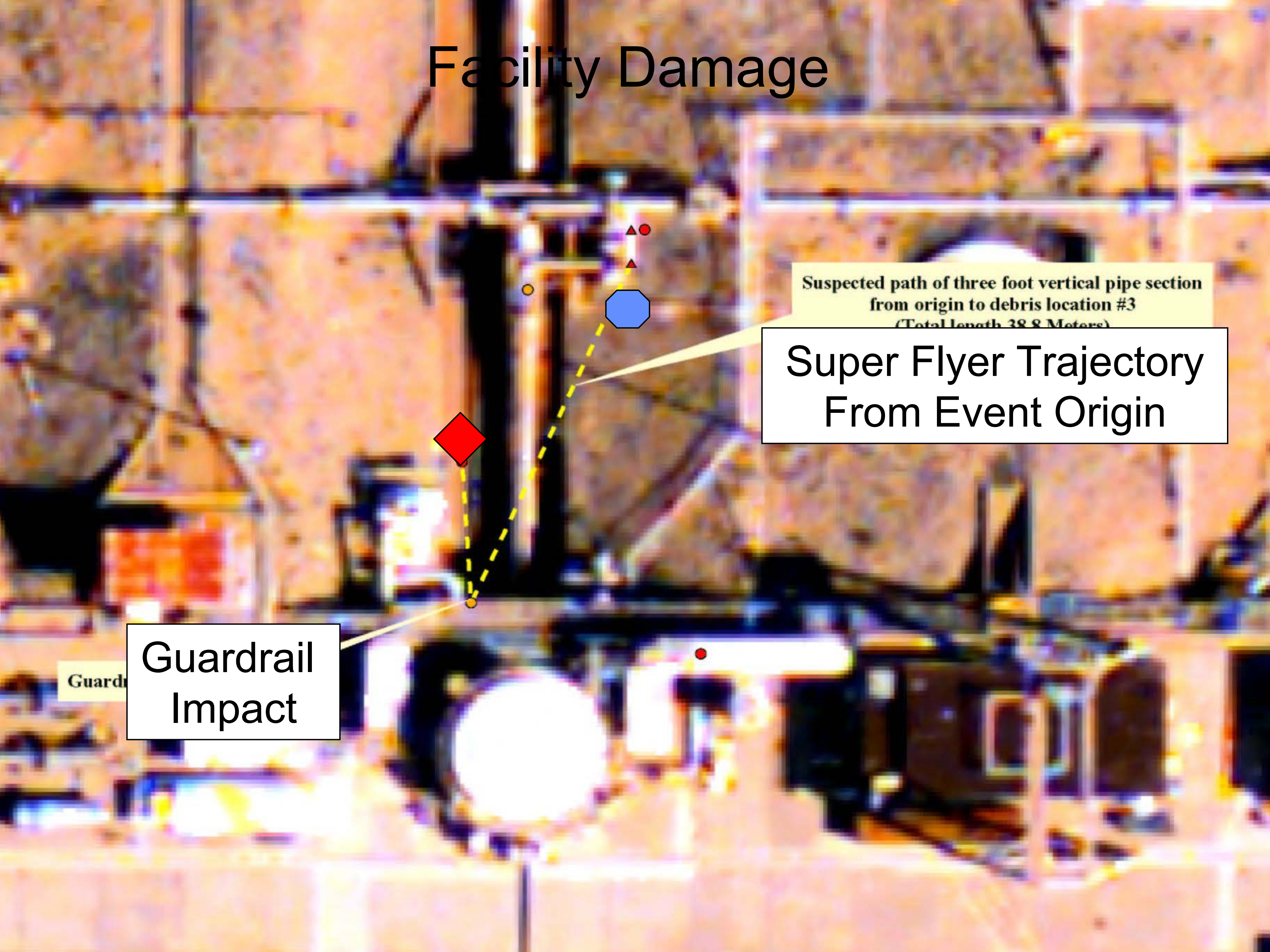
Mini Flyer

Dropper

Stay at Home

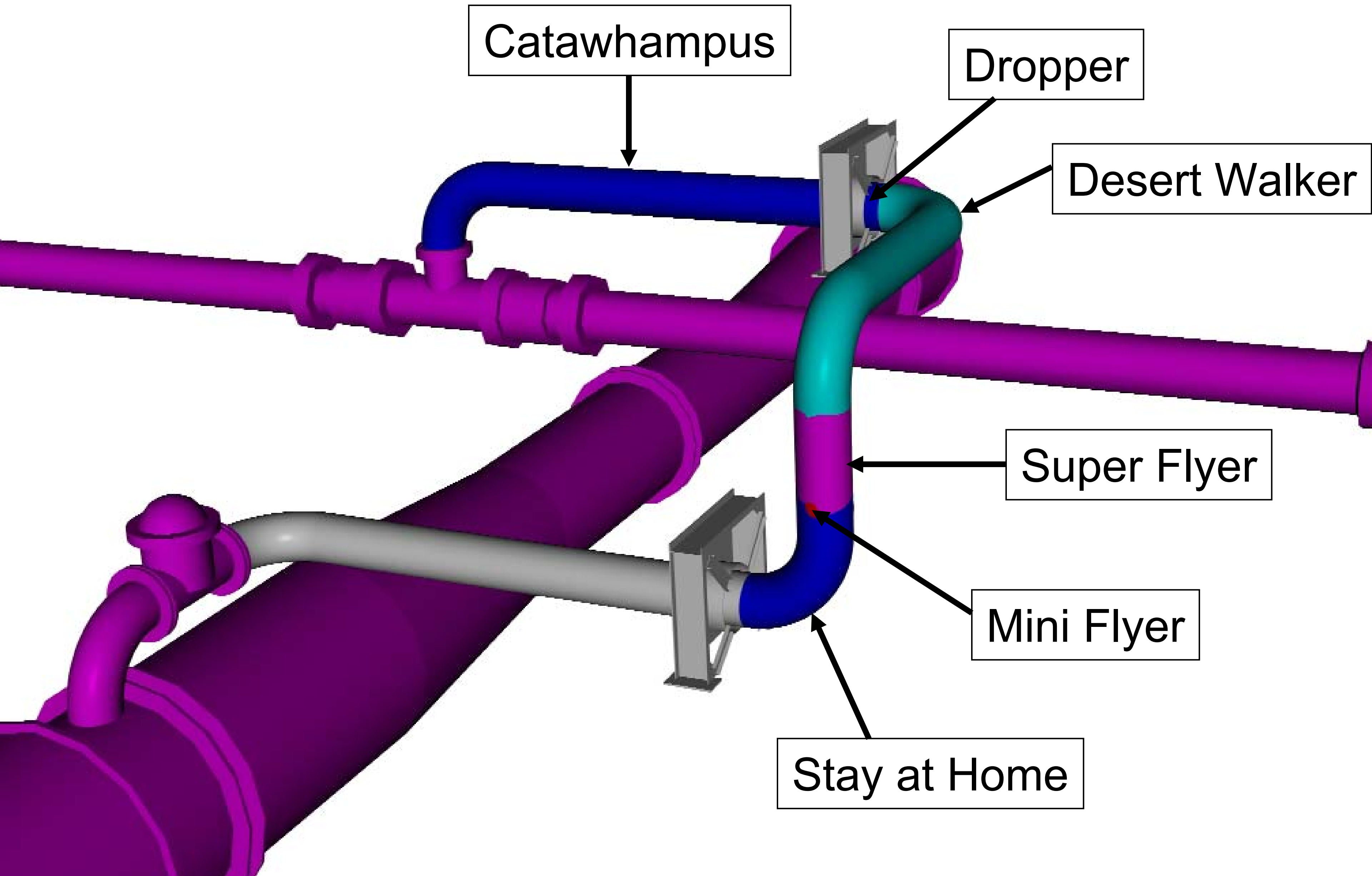
Desert Walker’s Journey

Facility Damage

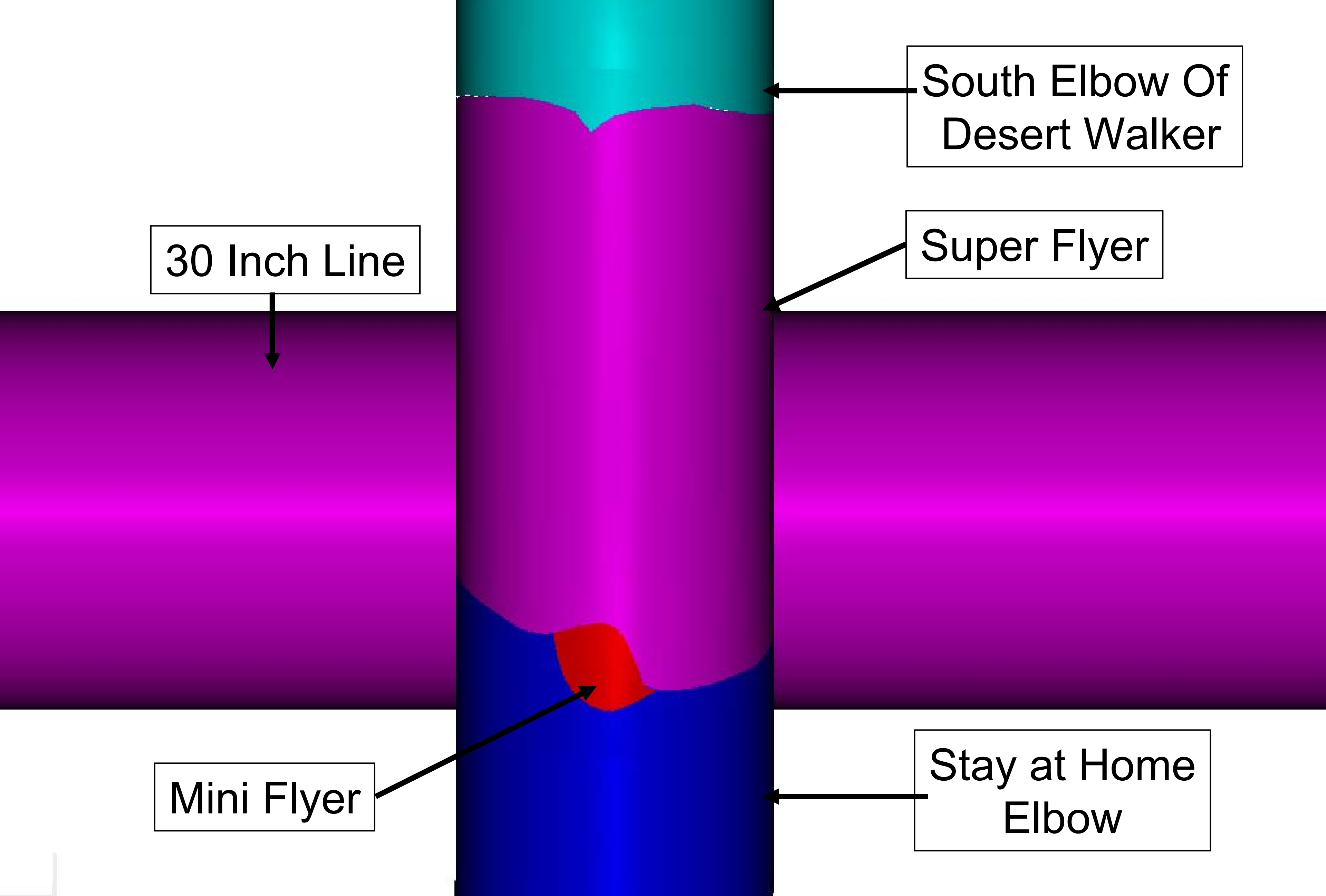


Super Flyer Damage to Guardrail

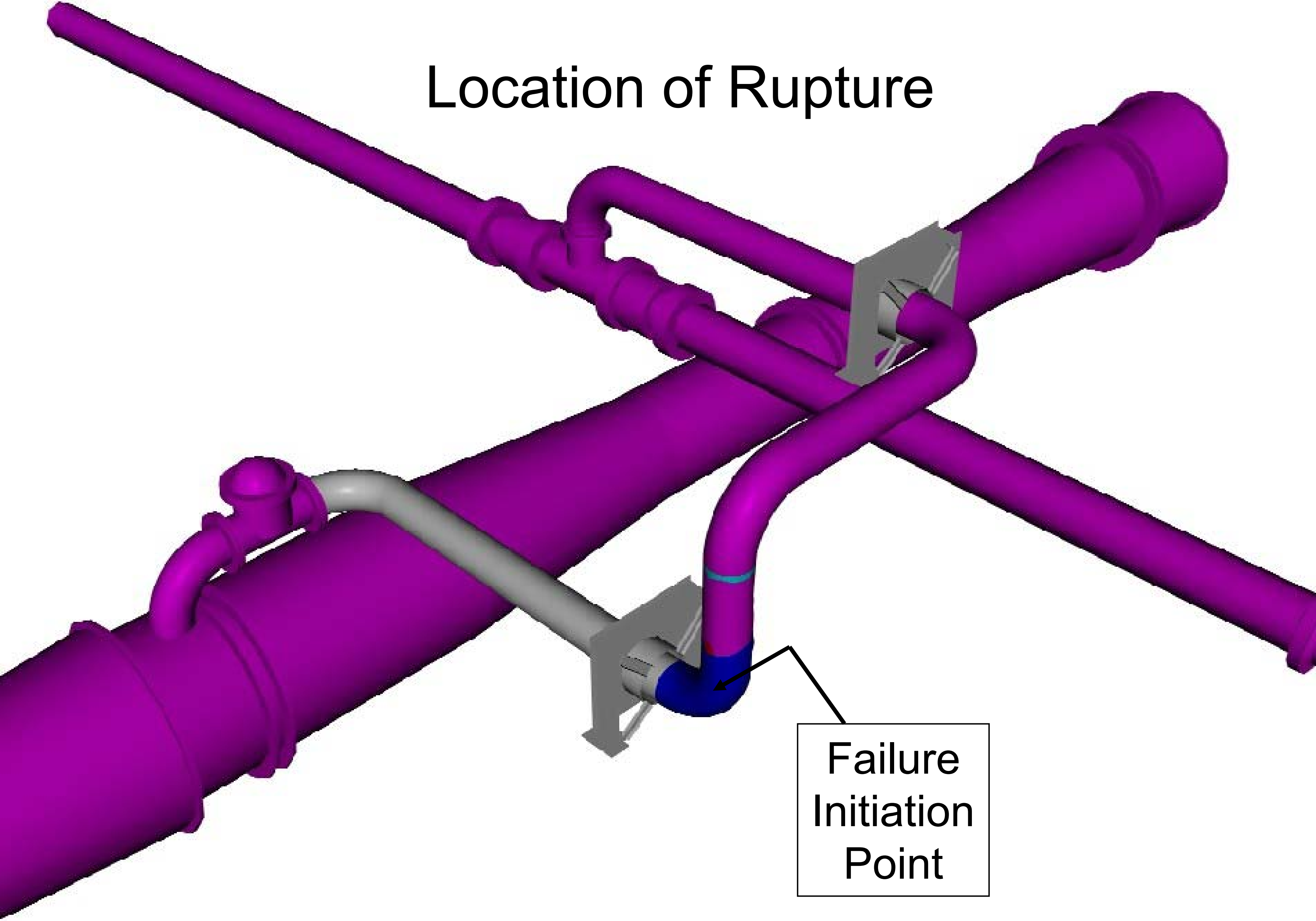
24” Expansion Loop Debris Reconstructed



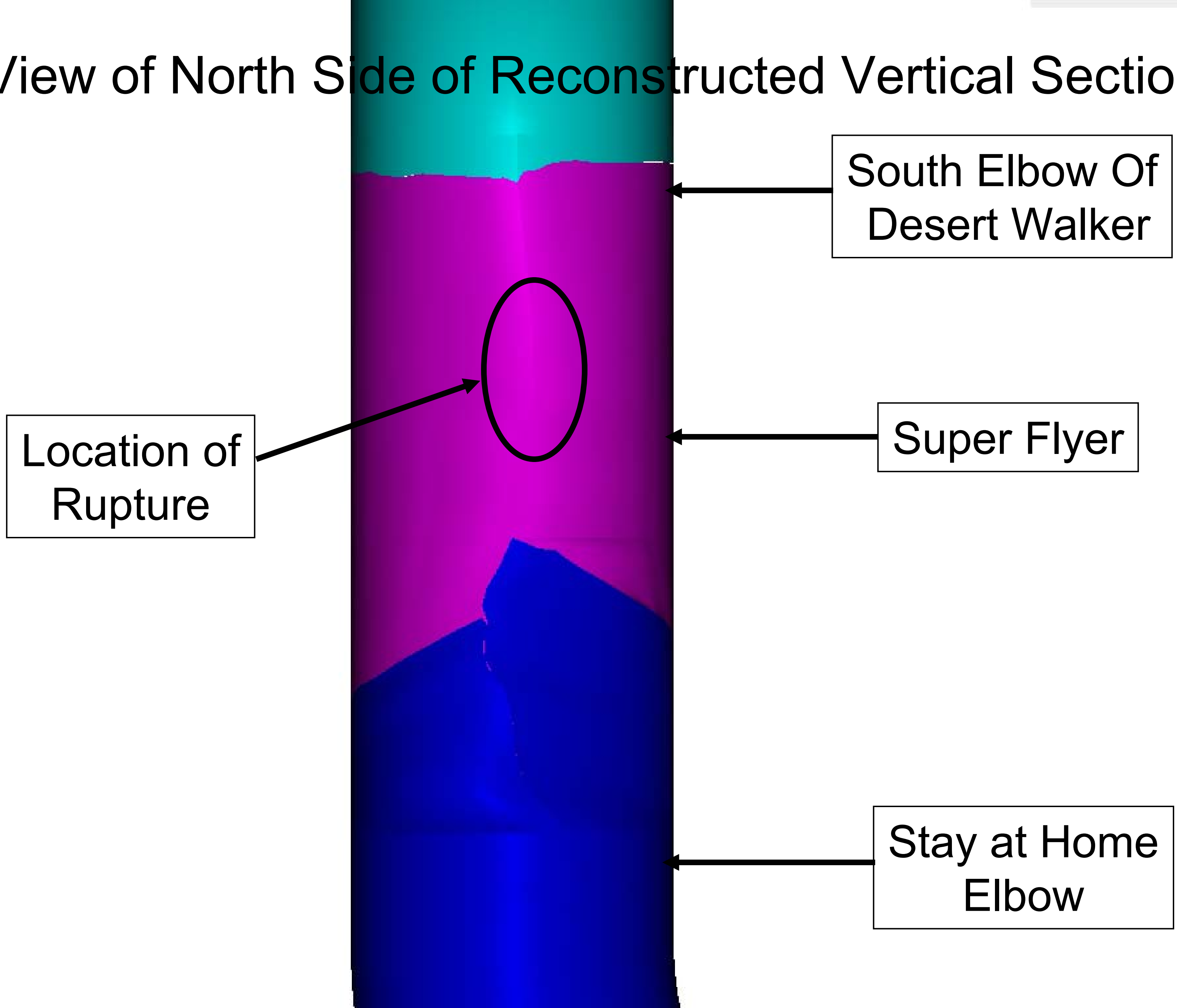
View of South Side of Reconstructed Vertical Section



Location of Rupture



View of North Side of Reconstructed Vertical Section



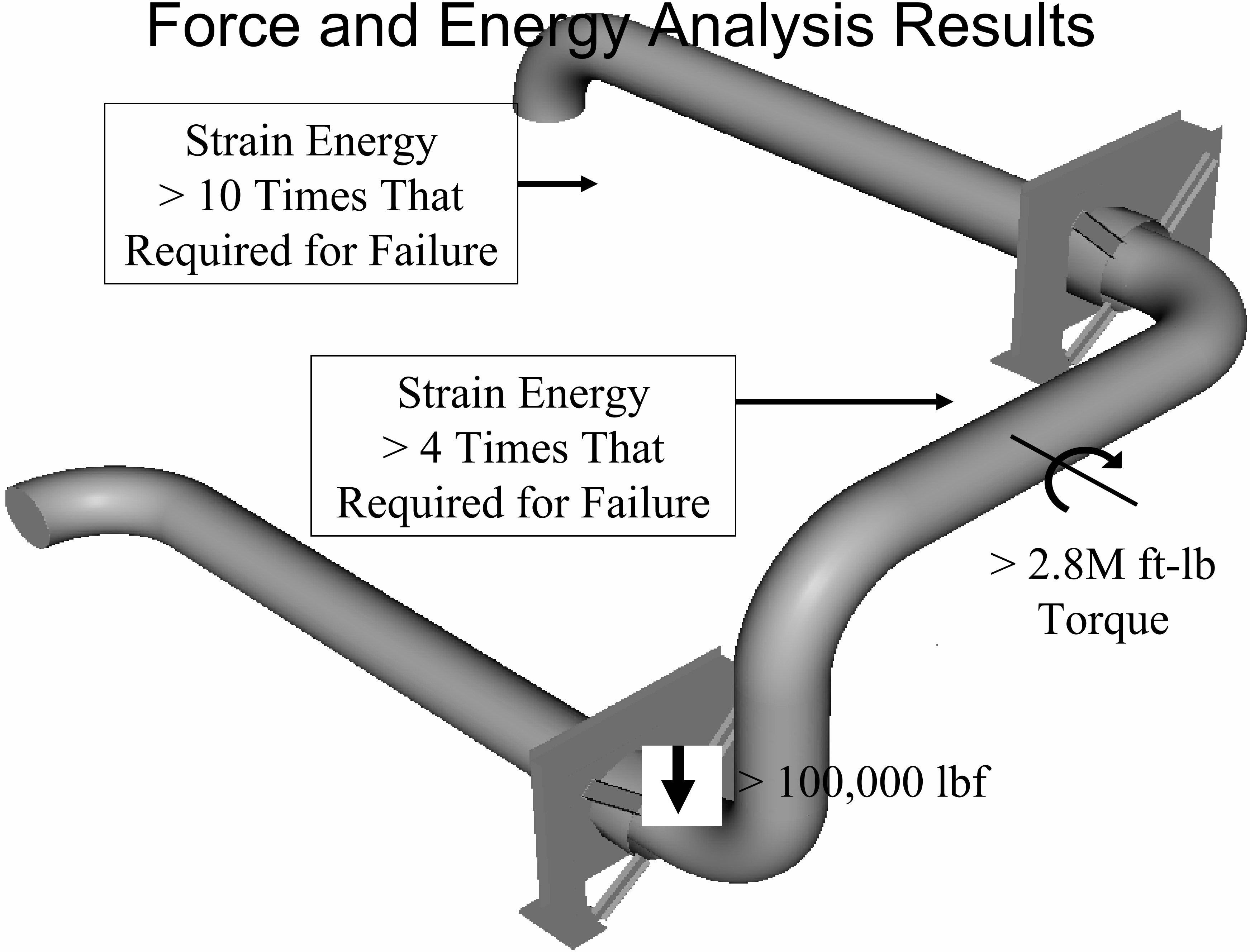
Location of Initial Failure

Upper Fracture
Arrest Area

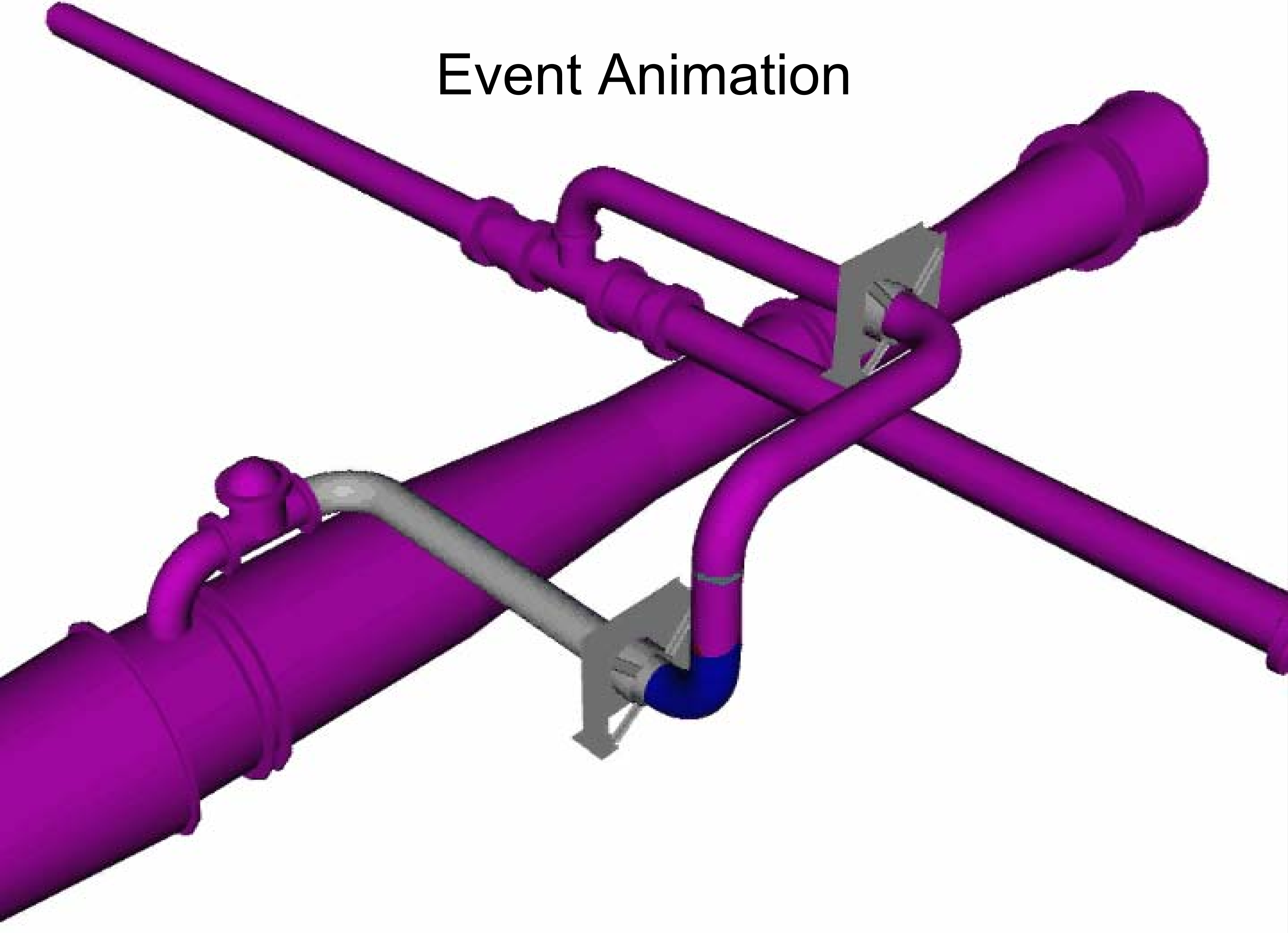
Thin Areas on
Super Flyer

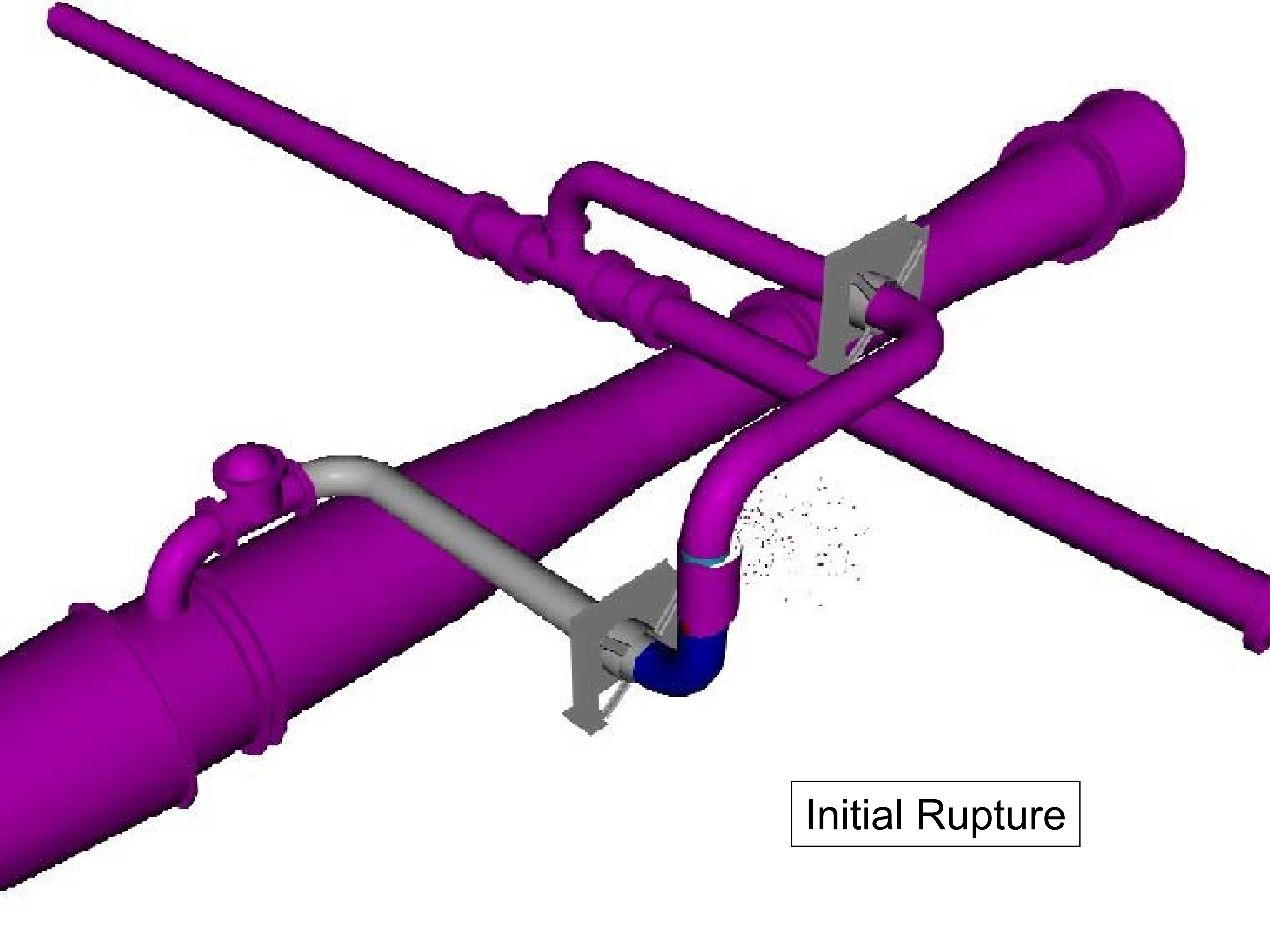
Lower fracture
Arrest Area

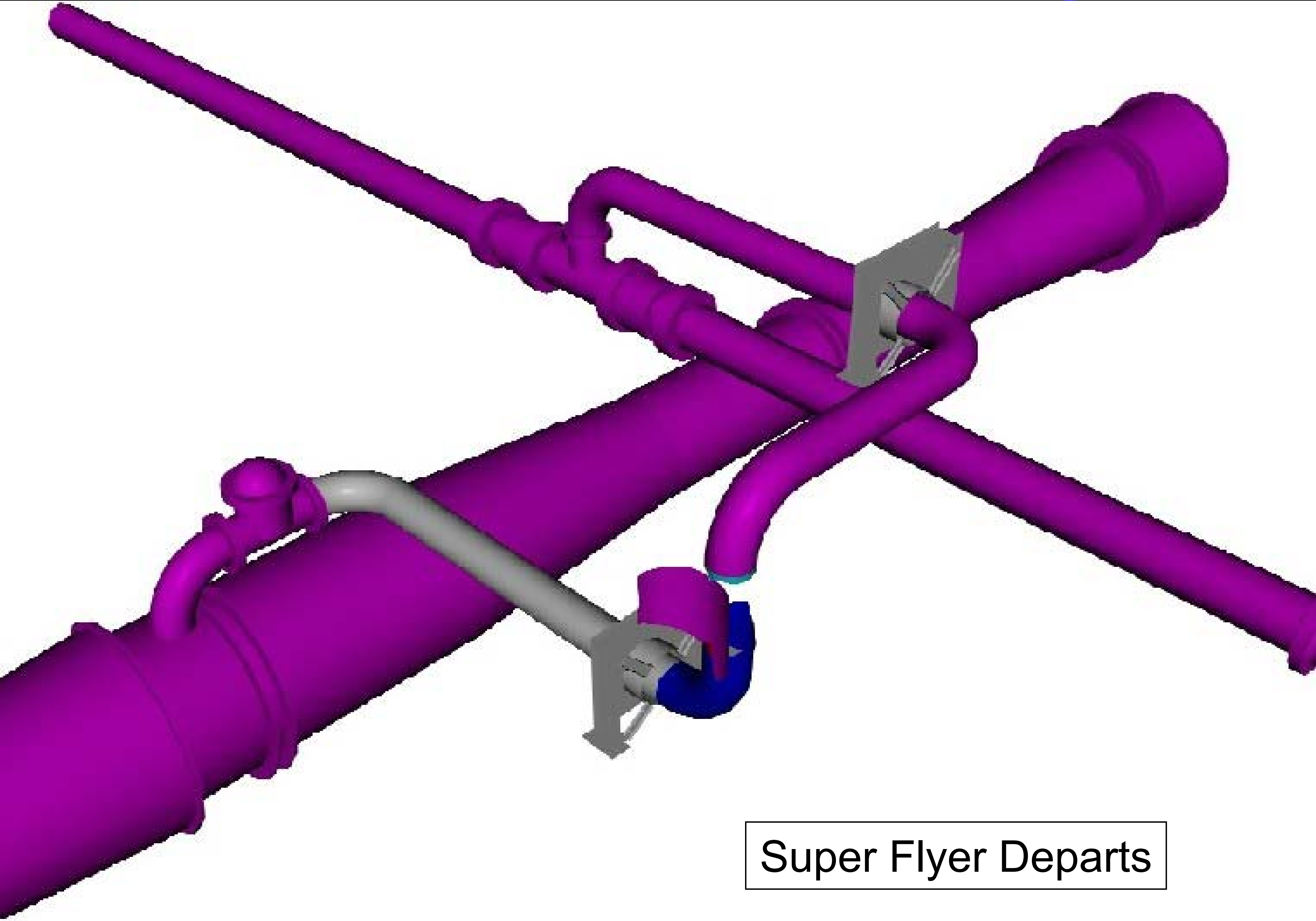
Force and Energy Analysis Results



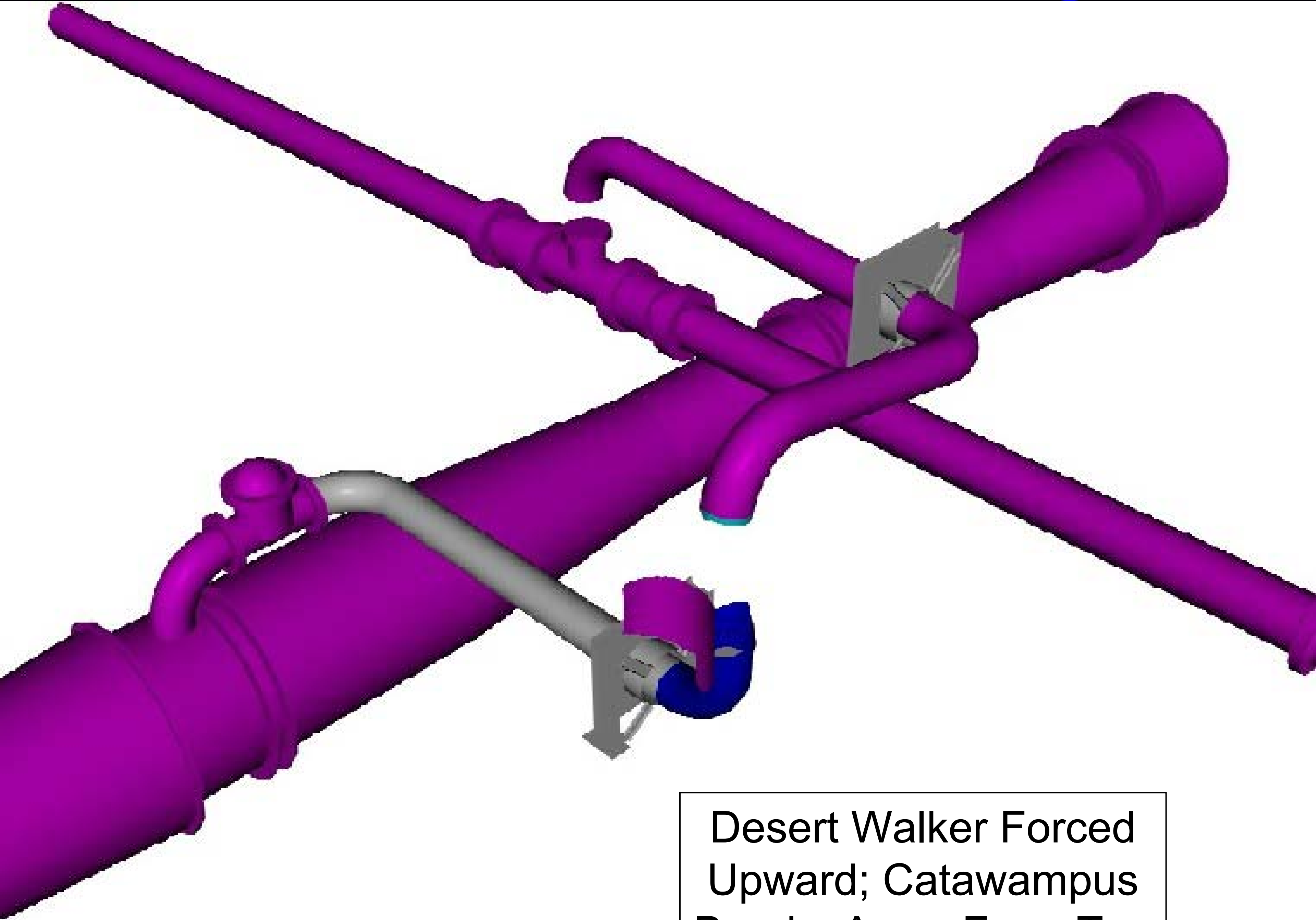
Event Animation



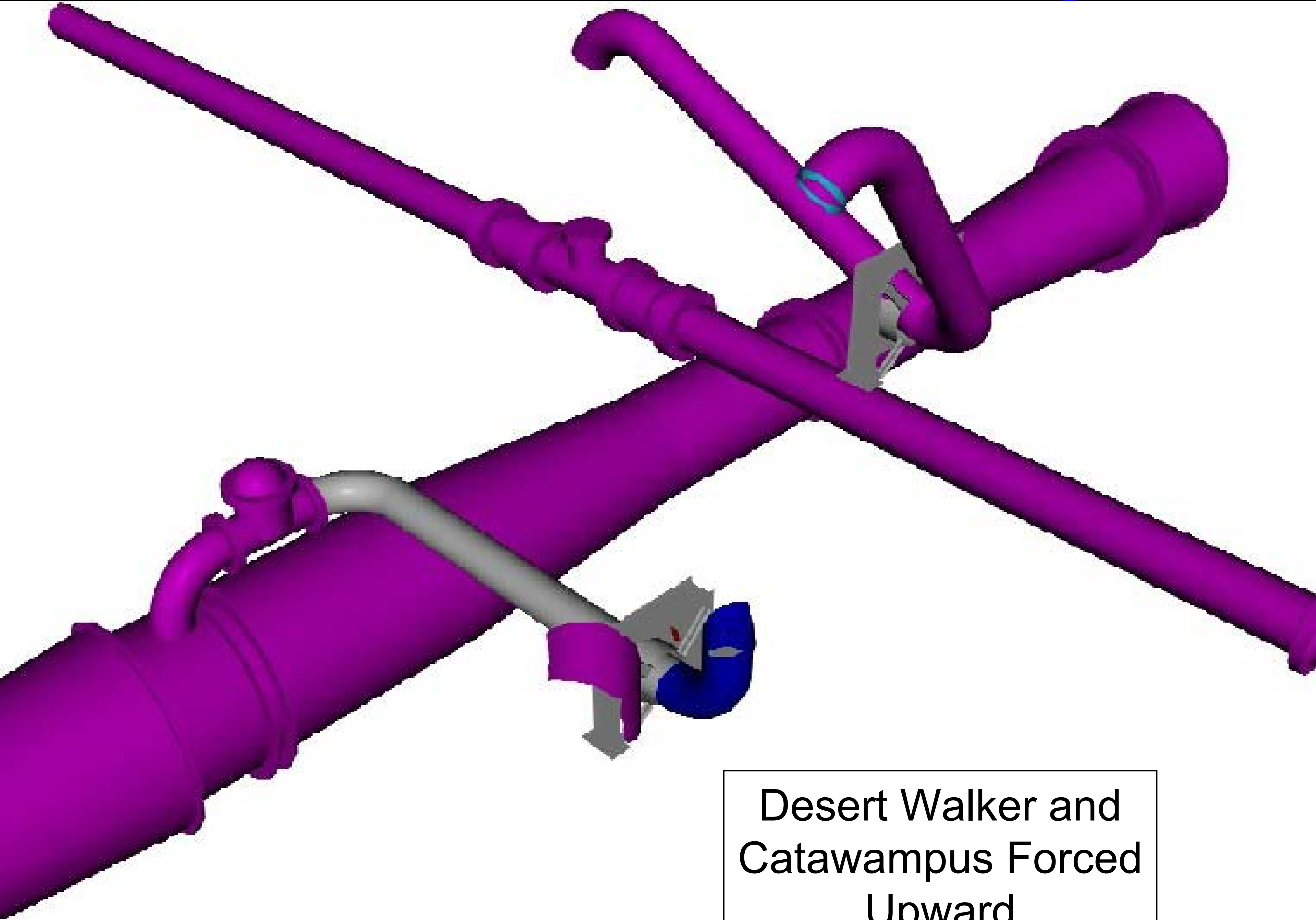

Initial Rupture



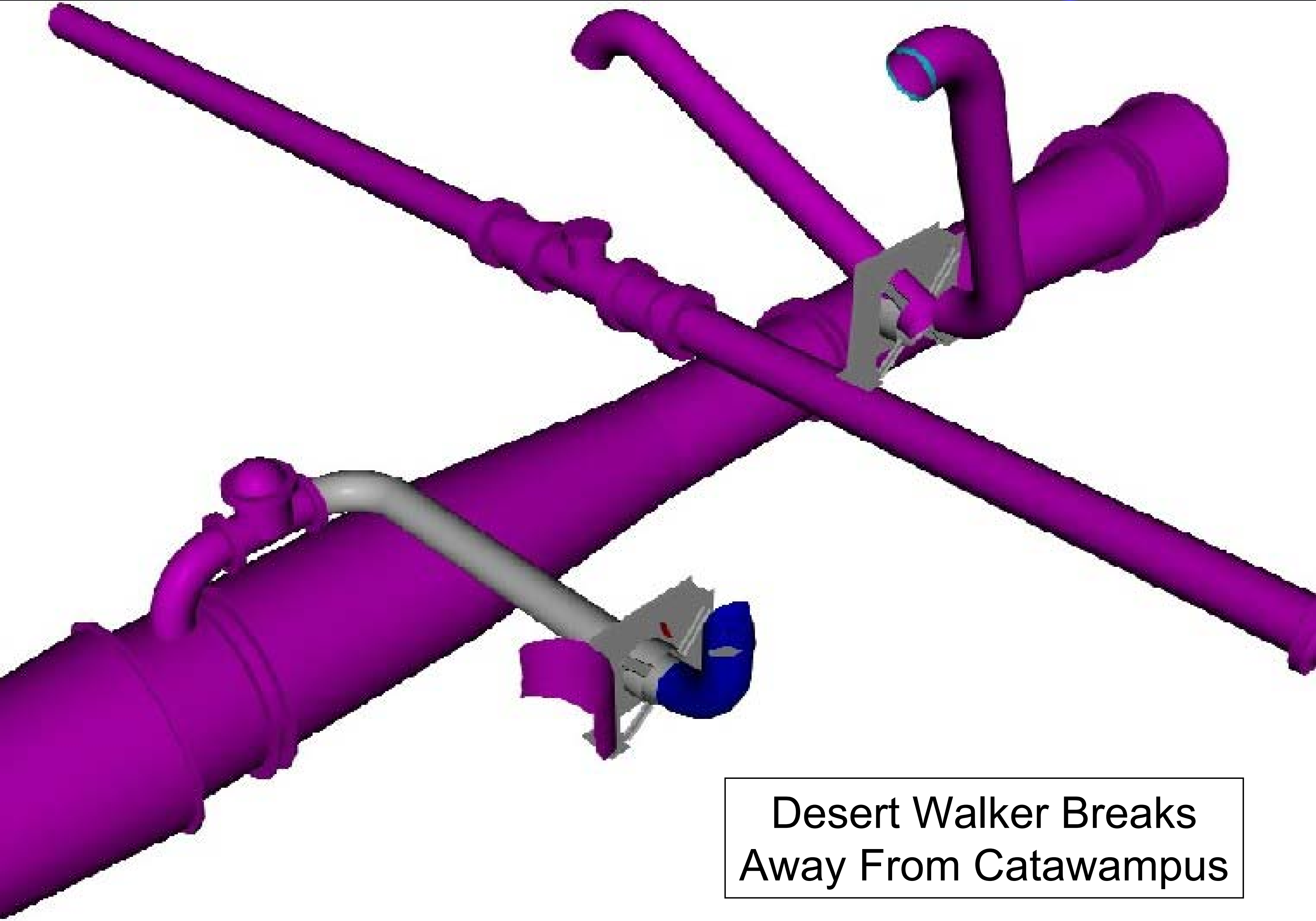
Super Flyer Departs



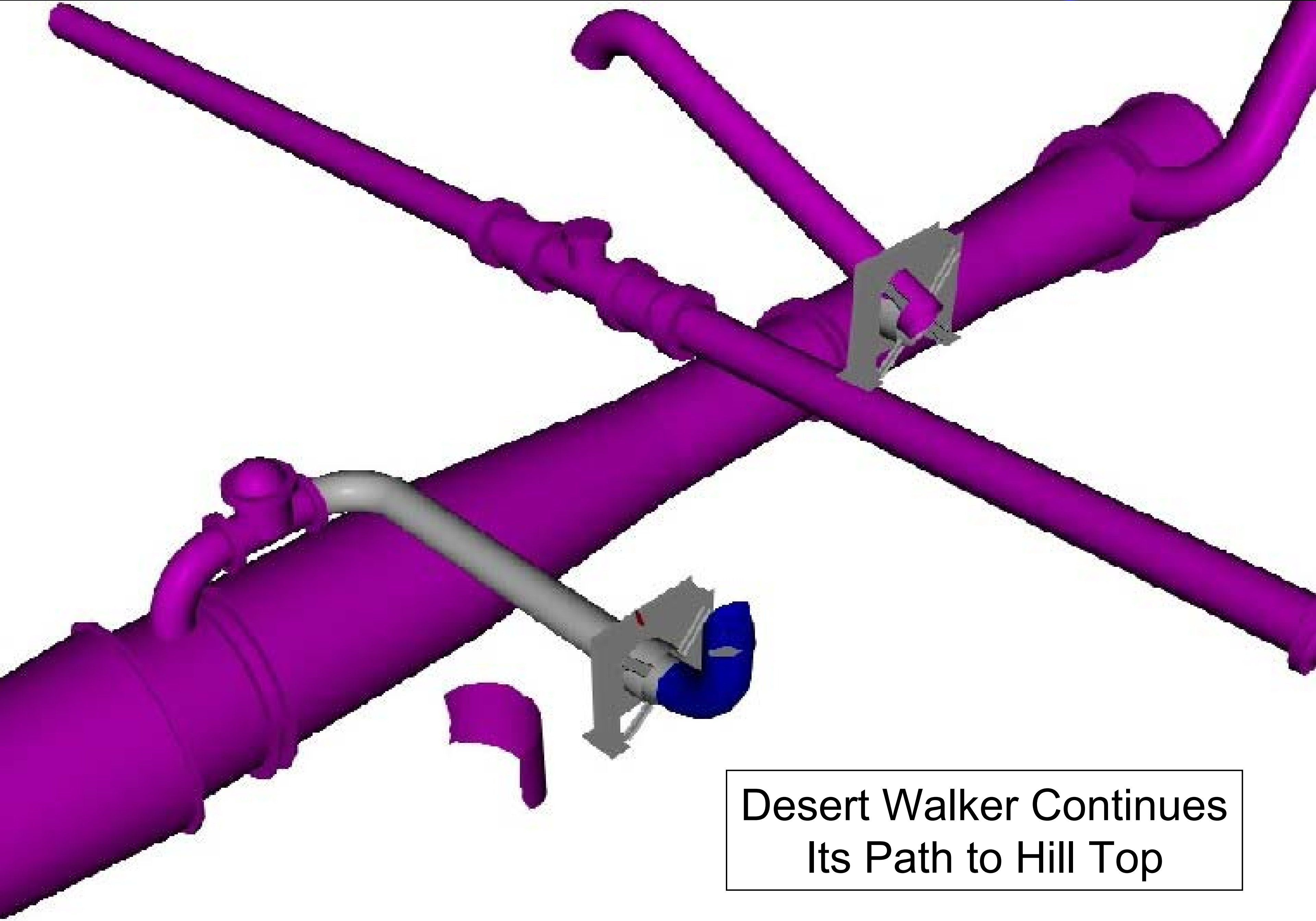
Desert Walker Forced Upward; Catawampus Breaks Away From Tee



Desert Walker and Catawampus Forced Upward



Desert Walker Breaks Away From Catawampus

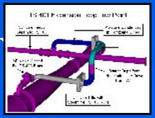


Desert Walker Continues
Its Path to Hill Top

Root Cause: Rupture of Vertical Section of 24” Pipe Due to Corrosion Induced Wall Thinning

- High Levels of Carbonic Acid in Steam
- Feed Water Not Treated
- Post Run Residual Water Not Drained

- LASS Configuration Led to More Thinning on North Side of the Vertical Section
  - TS 401 24” Valve Trapped Water
  - Diurnal Evaporation-Condensation Kept Wall



  - Vertical Section Subject to High Torsional Stress
  - Corroded Layers Broken Away Due to Erosion

Documentation Timeline Summary

- **Steam Line Condition, Failure Potential Documented 6/99**
  - Pressure Systems Inspection, Discrepancy Reports, Memos, Thickness Measurements, Safety Factor Analyses
- **Hazard Abatement Plan Submitted 12/99**
  - Procedural Control for Remote Operation
  - Semi-Annual Steam Line Inspections
- **LASS Reactivation System Readiness Review Held 5/00**
  - Closed All Hazard-identifying Paperwork by Referencing The HAP
- **Pressure Systems Inspections Performed Each June**
  - Missing Data Noted Each Year by Inspectors
  - LASS Steam Systems Recertified in 2001, 2002, 2003 Without Evidence of Required Steam Line Thickness Measurements
- **Pre-firing Open Paper Reviews Missed The Hazard**
  - Discrepancy Reports Were Closed Out in 5/00
  - Work Document to Perform Yearly Thickness Measurements Dismissed As "Routine Maintenance"

Findings

1. Primary Cause: Rupture of Vertical Section of 24” Pipe Due to Corrosion Induced Wall Thinning
   - High Levels of Carbonic Acid in Steam
   - Feed Water Not Treated
   - Post Run Residual Water Not Drained
2. LASS Configuration Led to More Thinning on North Side of the Vertical Section
   - TS 401 24” Valve Trapped Water
   - Diurnal Evaporation-Condensation Kept Wall Wet
   - Vertical Section Subject to High Torsional Stress
   - Corroded Layers Broken Away Due to Erosion

Findings (cont)

3. Failure to Adequately Assess Steam Line Led to Continued Use of an Impaired Pressure System
   - Only 13 Thickness Measurements
   - Less Than 4:1 Safety Factor
   - Inconsistencies in Thickness Data
4. Inadequate Follow-up of Known Steam Line Deficiency
   - No Expanded Steam Pipe Survey Performed
   - No Monitoring and Trending Plan
   - Requirements of Hazard Abatement Plan Not Met

Findings (cont)

5. Ineffective LASS Test Operations Approvals
    - Inadequate May 2000 System Readiness Review
        - Steam Lines Status Not Reviewed
        - Lack of Approved Hazard Analysis Listed as "No Constraint to Training Firings"
    - SRR Action to Complete the Hazard Analysis Ignored
        - Numerous Subsequent Training and Test Firings
    - Open Paper Reviews Ineffective
        - TPS to Take Yearly Wall Measurements Not Performed
        - Limited Participation – No Evidence of QA Participation
    - TRR's Not Required for Validation and Training Runs
        - TRR Only Required When Test Article Involved
        - Meets "Pre-Test Checkout" Allowance in 1700.1

Findings (cont)

6. Deficient LASS Hazard Identification and Control
   - Only a Draft HA and FMEA Exists – Controls Listed:
     - Remote Operation
     - Hydrostatic Test in 1998
     - Hazard Abatement Plan That Allows Operation Till 2009
   - Incomplete Hazard Abatement Plan for < 4:1 FOS
     - Developed in Place of a Waiver per HQ Code Q Guidance
       - Procedural Control for Remote Operation
       - Semi-Annual Steam Line Inspections
     - Created "Operational Comfort Zone" for Facility Personnel
     - Used as Rationale for Pressure Systems Certification and DR Dispositions
     - Reduced Management Visibility to the Hazard

Findings (cont)

7. LASS Test Team Desensitized to the Thin Wall Hazard
   - 45 Successful LASS Runs Since 1999
   - Leak Before Burst Capability of the Lines Reinforced by Occasional Small Leaks at Flanges
   - Primary Safety Objectives Being Addressed
     - Personnel Protected by Remote Operation Policy
     - Test Article Protected by Shutter Isolation Valve
   - Potential for Failures "Part of the Business"
   - May Have Contributed to Lack of Rigor in Aggressively Dealing with the Thin Wall Issue

Recommendations
LASS Re-Design and Operation

- Establish the Design, Operation, and Life Requirements as a Basis for Corrosion Allowance
- Assure that LASS Does Not Retain Moisture in Steam Lines Between Runs
- Develop and Implement a Corrosion Survey Plan That Includes Trending and Pass/Fail Criteria
- Investigate Methods to Neutralize Carbonic Acid
- Determine Feasibility of Removing Insulation From Steam Lines to Reduce Exterior Corrosion

Recommendations
LASS Re-Design and Operation (cont)

- Assure That Steam Line Supports, Guides, and Restraints do Not Affect Ability to React to Thermal Expansion
- Implement Remote Electrical Safing of LASS Facility Systems
- Assess PPE and Air Monitoring Tools in Block Houses
- Examine Control Room Layout and System Status Displays to Aid in Assessing Facility & Test Conditions
- Add External Area Status Lights to 300 and 400 Area Block Houses

Recommendations
WSTF Facility System Processes

- Implement Measures to Renew the Appreciation of:
  - The Hazards Associated with WSTF High Energy Systems
  - The Importance of Understanding All Aspects of High Energy Facility System Conditions
- Complete the LASS Hazard Analysis and FMEA Prior to Further Operations
- Implement Increased Thoroughness and Follow-Through in the System Readiness Review Process

Recommendations
WSTF Facility System Processes (cont)

- Establish Policy For When a TRR is Required For Check-out Operations of High Energy Systems
- Implement Increased Rigor in the WSTF Pressure Systems Inspection Program, Including the Process of Tracking and Follow-up on Resolution of Non-Compliances
- Conduct a Review of Facilities for Which Documented Degradation Exists That, if Left Unabated, Could Pose Hazards to Personnel and Facilities

Lessons Learned

- Steam Piping moment arms must kept short enough that the pipe strength is not exceeded during a failure
- It is difficult to determine the location of old pipe wall thinning in complex installations without 100% surveying
- NDE techniques for determining steam pipe wall thickness can be inconclusive due to pipe wall corrosion
- Piping insulation can trap moisture on the exterior of the pipe and accelerate corrosion
- Piping designed to Leak Before Burst capability that has experienced wall thinning will ultimately transition to a "burst before leak" situation if the wall thinning is not arrested

Lessons Learned (cont)

- The corrosive environment in wet steam lines during down time can be worse than during active use
- Elevated levels of carbon dioxide in steam system water can lead to excessive amounts of carbonic acid which is highly corrosive to carbon steel piping
- Evidence of rust scale deposits around steam line drains or exhaust ducts is an indicator that internal corrosion and erosion is taking place
- Hydrostatic pressure testing of old or modified fluid handling lines is not an effective means of verification of long-term pressure integrity

Lessons Learned (cont)

- Instrumentation data sample rate and data quality should be high enough to catch the possible events that the transducer might measure, not just the expected events
- System operational capability, such as design life, must be established and documented at the initial design to allow appropriate decisions as the system approaches its capability limits
- Post-implementation problem solutions must utilize a "systems approach" in order to avoid creating a worse problem in another design feature than the problem being corrected

Safety Director Reflections

- Keeping old systems alive can drive uncomfortable compromise
- Initial wall-thinning data indicated 33% reduction in margin over 35 years -- not an alarming pace (if it was accurate)
- "Why do we need a hazard analysis when we know the worst case?"
- If we can't save the facility, save people
- Risk changes just like management

WSTF Industrial Hygiene Case Study

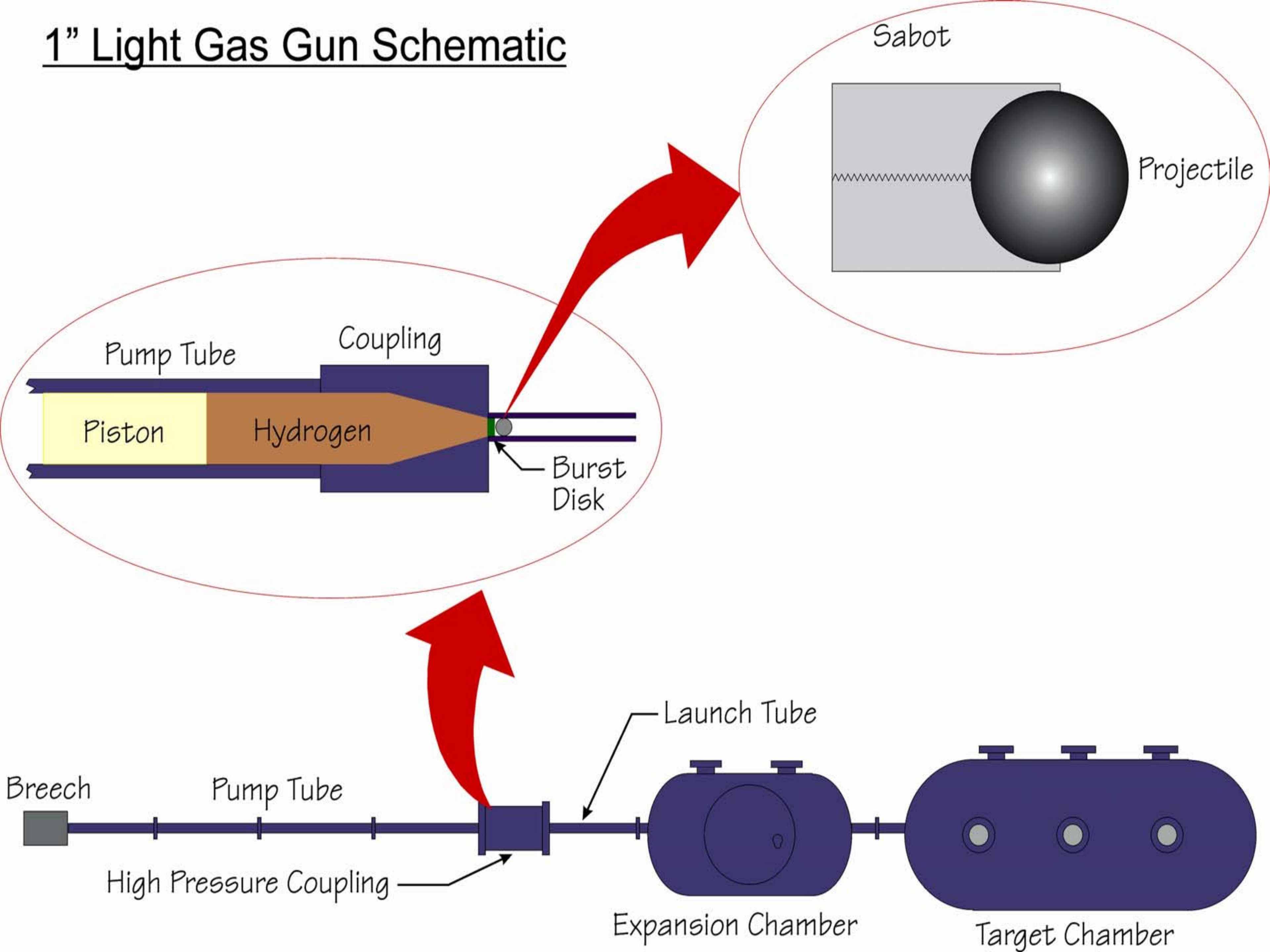
Control of Hypervelocity Exposures -- Recognition, evaluation, and control of gunpowder decomposition products

Recognition

Hypervelocity Team complaints voiced in Safety Working Group and Respiratory Protection Recert. (12/2001)

- Loss of sense of smell (anosmia) noted during qualitative fit testing for respirators
- Workers found that they had similar problems when they compared notes
- They also had complaints of skin and mucous membrane burning and upper respiratory irritation
- WSTF IH was called in to evaluate.

1” Light Gas Gun Schematic



Evaluation

Industrial Hygiene initial assessment (Jan. 2002)

- Gases were leaking from the guns after firing
- Gases were released when the breech was opened
- Possible air contaminants included: benzene, acetaldehyde, carbon monoxide, methane, xylene, toluene, 1-butene, 1-3-butadiene, and various other gases.
- 2,6-Toluenediamine (an irritant) was part of the solid left in gun and potentially a particulate air contaminant.
- Some breathing zone sampling on workers found benzene at 50% of the TLV (the TLV is 0.5 ppm TWA).

Control

Team approach from the start

- **WSTF IH - focus on assessment and controls**
- **Honeywell IH assistance and provided recommendation appropriate PPE**
- **Medical - Occupational Health Physician & Nurses provided physical evaluations and consultation**
- **JSC/SD IH and Medical - Provided consultation and consulted with Hypervelocity Team**
- **Hypervelocity Team - Working on improved control measures.**
- **Keystone committee - Facilitated employee communications and concerns**

Response

<u>Immediate action taken</u>

- SCBA and protective clothing required after firing the gun until cleaning completed. Building not reentered until next day.
- Improvement of gun tube seals.
- Sealing of the accelerated reservoir (AR) and breech with covering outside of the gun tube.
- Medical evaluations of all personnel involved
- Frequent communication between workers, IH, Management and medical.
- Continued IH evaluation to assess problem assist in the development of effective controls.

Implementing Controls

Long term controls

- Changed purging times and purge locations in the guns (purging more of the gun after firing).
- Improved seals on the guns
- Sealing of the accelerated reservoir (AR) and breech with covering outside of the gun tube.
- Permanent procedure changes in purge process and duration.
- Exhaust stack improvements.
- CO monitoring at every shot.

Subsequent Assessment

Monitoring has consistently shown exposures are effectively controlled

- No detected hydrocarbons (and specifically benzene), CO, or particulate after firing or when opening guns after firing.
- PPE has been relaxed from initial SCBA to air-purifying respirators and now air purifying respirators used only right after firing and leaving the bunker.
- Skin protection during cleaning still used.

Controls Effective

- Contaminants stayed in guns after firing.
- Purges exhausted contaminants out of the guns and building - none detectable
- Sampling for particulate was done which verified that it was also controlled.
- Reentrainment of exhaust gases addressed by design changes to exhaust stack
- Continued IH monitoring done in 2002 and planned for out years (lesser frequency).
- Symptoms of workers have stopped. Sense of smell has was reported to have returned. Employees satisfied with controls and WSTF response to concerns